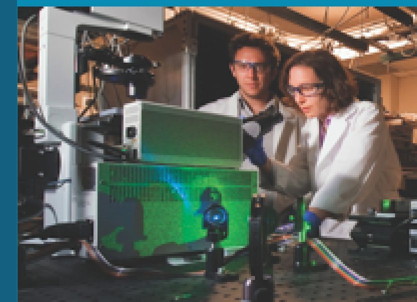
SAND2021-9123C

Sandia National Laboratories

Security, Safety, and Safeguards (3S) Risk Considerations for Small Modular Reactors (SMRs)



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Safety, Security, & Safeguards Challenges for SMRs

“By-design” concepts are all popular in analyses of SMRs

Common economic arguments for SMR safety, safeguards, and security
- The ability to still achieve the same levels of risk reduction when resources available for safety, safeguards, and security are reduced

Applicability of current safety, safeguards, and security approaches
- How can passive safety systems be modeled in traditional probabilistic risk assessment (PRA)-based techniques

Lack of robust and appropriate regulatory regimes to bound risk SMRs

Safety, Security, & Safeguards Technical Evaluations

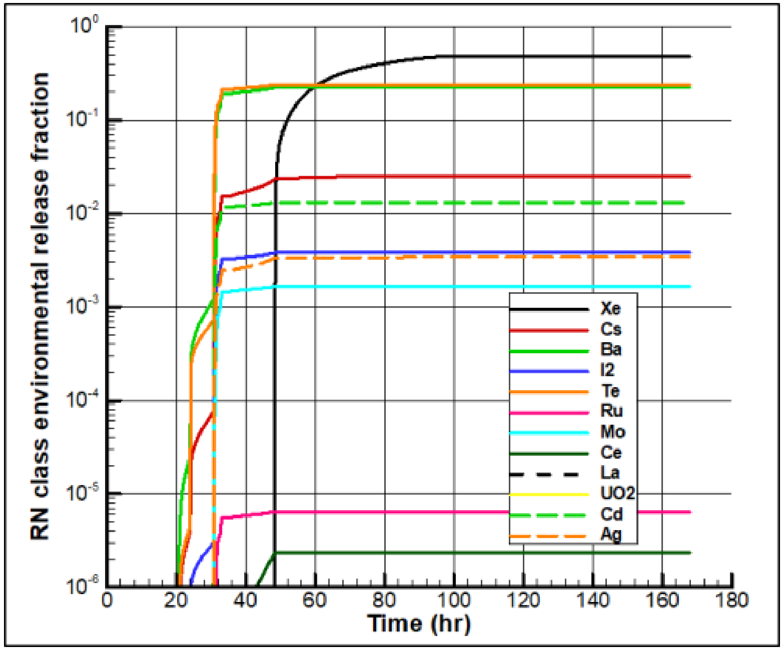
Safety Technical Evaluation

- Goal: investigate SMR safety in the event of short term station blackout will complete loss of all electrical power
- Tools used: MELCOR, ORIGEN-ARP, MelMACCS

#	Summary	Containment Status
1	Total loss of on/off-site power with disabled passive safety systems (e.g., baseline)	Intact, fully functional
2	Total loss of on/off-site power with disabled passive safety systems with lowered pressure thresholds	Degraded, still functional
3	Direct containment breach with large diameter hole (e.g., upper bound)	Breached
4	Total loss of on/off-site power with functional passive safety systems (e.g., a best-case scenario)	Intact, fully functional

Key Takeaways:

- Hypothetical SMR has a good degree of safety
- Support the argument that the small core sizes and low core power densities slow severe accident progression
- Need to develop a new safety metric—from release thresholds → offsite health effects
- Slow accident progression (~20 h to first release)→ potential impact on location of



Radionuclide class release fraction for safety

Safety, Security, & Safeguards Technical Evaluations

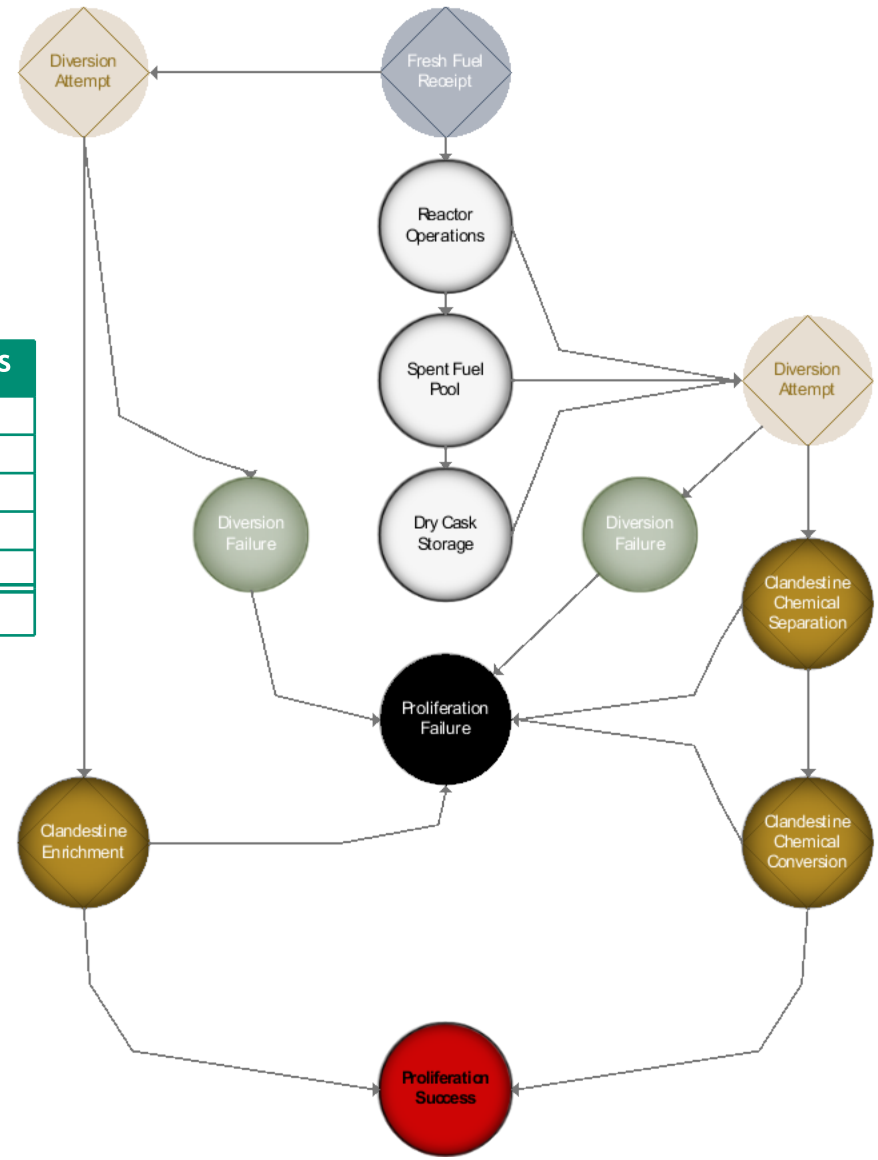
Safeguards Technical Evaluation

- Goal: investigate SMR safeguards in the event of an attempted diversion (or production) of SNM
- Tools used: PRCALC

#	# of Rxs	Safeguards
1	1	Yes
2	1	No
3	2	Yes
4	2	No
5	10	Yes
6	10	No

Key Takeaways:

- Additional safeguards can further reduce already fairly low likelihood of proliferation success
- Indicated that the safeguards impact of a single SMR was on par with other electricity -generating nuclear facilities
- Suggest that an increase in SMR reactor production globally (more material) may challenge the international nuclear safeguards regime
- Different SMR parameters *may have*



PRCALC Markov-model for Safeguards scenario 1

Safety, Security, & Safeguards Technical Evaluations

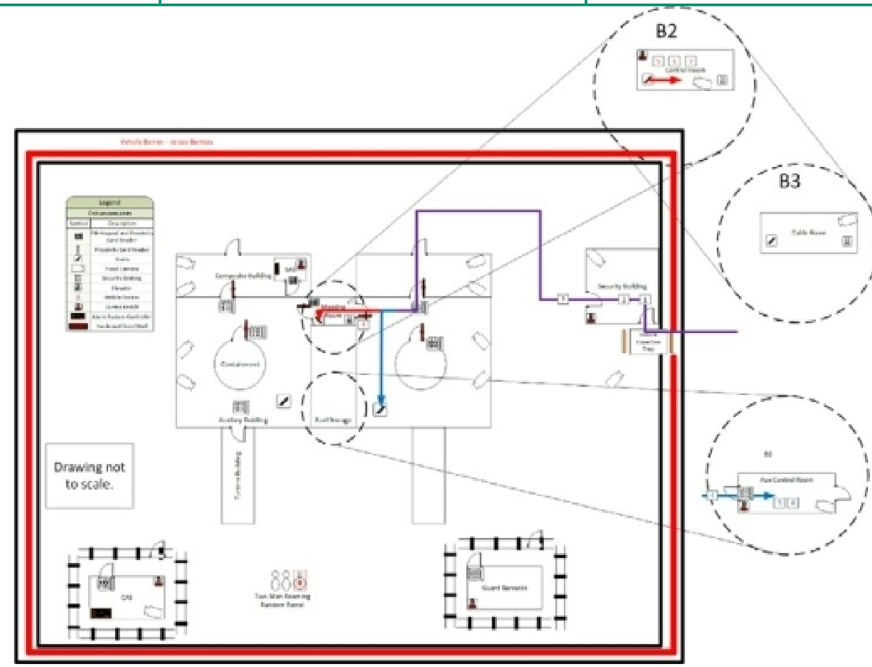
Security Technical Evaluation

- Goal: investigate SMR security in the event of adversary sabotage for a range of PPS capabilities
- Tools used: DEPO analytical approach

	Initiating Event	Path Summary	Deviations from notional DBT
1	Breach with vehicle bomb	Use truck bomb to destroy control room, then attack auxiliary control room	+ Ammonium nitrate vehicle bomb
2	Access via counterfeit badges	Pass through personnel portal, then take over main/auxiliary control rooms	+ Active non-violent insider
3	Insider escorts into facility	Pass through personnel portal, then take over main/auxiliary control rooms	+ Active non-violent insider
4	Overt attack on entrance portal	Kinetic attack on entrance portal, then take over main/auxiliary control rooms	None

Key Takeaways:

- Sole reliance on offsite response to deny sabotage missions is insufficient, despite the cost savings
- No critical detection point existed for any low security posture-based scenario
- Critical detection points existed for onsite response for all *medium* & *high security posture*-based scenarios
- Critical detection points existed for offsite response only for adversary missions 1 & 4 against *high security posture*-based scenarios



Medium Security Posture Level Adversary Missions 2, 3 and 4.

Integrated 3S Technical Evaluation for SMRs

3S evaluation → characterize interactions between safety, safeguards, and security for SMRs

- Identifying conflicts & leverage points
- Locating interdependencies
- Determining influence of interdependencies

Element/Action	Safety Effects	Security Effects	Safeguards Effects
Passive vs. active safety systems	Smaller risk of malfunctioning active systems	New potential target & vulnerabilities	N/A
Physical separation of reactor trains	Reduce common cause failures	Increased difficulty for adversaries to sabotage plant	Increased potential to conceal sections of facility from inspections
Consolidation of locations storing nuclear material	N/A	Increases attractiveness of material storage locations	Reduces opportunity for proliferators to divert nuclear materials

Conclusions

Preliminary 3S technical evaluation partially supports popular safety, safeguards, and security claims for SMRs

Support calls for “by-design” approaches to address risk complexity in SMRs

- How interdependencies may impact the efficacy of “inherent” or “passive” safety systems

Interdependencies are subject to additional nuance contingent upon operational-specific details (e.g., mitigations *may* look different in one country than in another)

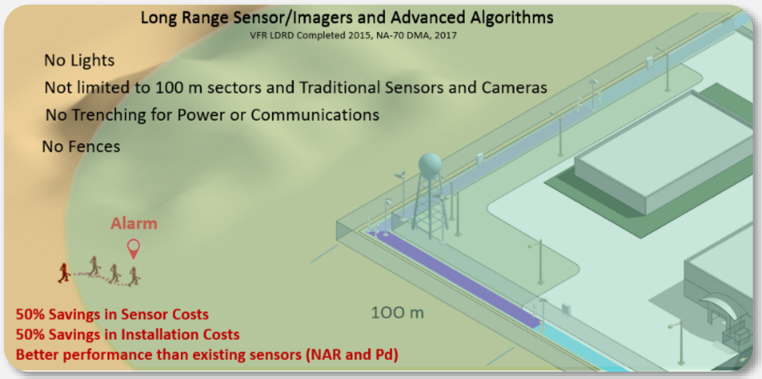
Analytical assumptions were carefully discussed and benchmarked (where possible) against related data or subject matter expertise

An integrated 3S framework could be used to evaluate SMRs as a “systems-level” whole to better characterize, evaluate, and manage increasing risk complexity

QUESTIONS?

SeBD in Practice – Facility Examples

Example 1: Earlier Detection and Assessment



Incorporating elements of earlier detection & assessment into facility design will:

- Reduce overall lifecycle costs
- Reduce nuisance alarm rates (NARs)
- Increase in adversary probability of detection (Pd)

SeBD Outcome

Small increase of installation cost

Large improvement and reduced long-term O&M costs

Example 2: Siting

- Below-grade siting to increase adversary delay time & potential to contain acts of radiological sabotage
- Placement of SMR/AR in areas with wide, flat terrain increased detection capabilities

SeBD Outcome

Incorporate physical siting characteristics

Improved ability to achieve security functions

Example 3: Leverage Safety Attributes for Security

- Safety Needs: preclude or mitigate human health and environmental consequences
  - Ex: Emergency Planning Zones (EPZ)
- Security Potential:
  - Use EPZ as Protection Zone for start of detection and assessment

SeBD Outcome

Leverage existing infrastructure

Improved performance

Versus ***adding*** extra infrastructure to demarcate protection zones